

TITLE OF THE INVENTION:

COOLING SYSTEM FOR MOTOR AND COOLING
CONTROL METHOD

BACKGROUND OF THE INVENTION:

~~(Field of the Invention)~~

The present invention relates to a cooling system for a motor and to a cooling control method.

5 ~~(Prior Art)~~

An electric vehicle₁ including a hybrid vehicle₁ has a ~~constitution of~~
supplying system in which power is supplied to a driving motor from a battery
via a power converter₁ and has a forced cooling means is provided for
suppressing a temperature rise of the power converter and driving motor due
10 to heat generation ~~generated~~ in correspondence with the operations of the
power converter and driving motor.

The forced cooling means is structured so as to ~~forced-force~~ feed a
refrigerant₁ such as fresh air or a cooling liquid (an antifreezing solution)₁ to
the power converter and driving motor when the temperatures of the power
15 converter and driving motor rise up to a predetermined cooling start
temperature, thereby ~~forced-cool~~ force cooling them.

For example, ~~the inventions described in the~~ a patent document 1
(Japanese Application Patent Laid-open Publication No. Hei 07-213091) and
~~the~~ a patent document 2 (Japanese Application Patent Laid-open Publication
20 No. Hei 08-33104) ~~are disclose~~ a cooling device for controlling the cooling air
speed according to the temperature of heat radiating fins of a semiconductor
element of a power converter, which is used for controlling an electric vehicle
motor.

Further, ~~the invention described in the~~ a patent document 3 (Japanese Application Patent Laid-open Publication No. Hei 10-210790) ~~is~~ discloses an inverter cooling device for an electric vehicle for detecting the temperature of a semiconductor element of an ~~inverter~~ which is used for supplying a current
5 to a motor and for controlling the flow rate of a refrigerant according to the temperature of the semiconductor element and the change rate thereof.

Further, ~~in the~~ a patent document 4 (Japanese Application Patent Laid-open Announcement Publication No. 2001-527612), discloses a cooling device for detecting the temperatures of a temperature control fluid and
10 ambient air so as to control the temperature of the engine oil of a vehicle at a proper temperature ~~is described~~.

For a driving motor of a driving device for an electric vehicle, a DC commutator motor or an inverter driving type DC non-commutator motor is generally used, and the power supply to such a driving motor is controlled by
15 a power converter, such as a chopper circuit or an inverter circuit. During the operation (power supply control), in the driving motor, a loss due to ~~flowing the~~ flow of a current through a coil or a mechanical loss during high-speed rotation is caused, and also, in the power converter, a loss is caused during power supply to a semiconductor element for power conversion control or at
20 the time of switching, ~~and these~~. These losses are finally converted to heat, and the total amount of heat reaches several kW at the maximum.

Such generation of heat causes a temperature rise of the driving motor and power converter, and when it is left as it is, the driving motor and power converter cannot ~~prove~~ exhibit a predetermined performance due to the
25 temperature rise. Furthermore, the insulating material is reduced in the withstand voltage and is finally destroyed ~~finally~~, so that the generated heat must be removed.

As a forced cooling means, which effectively radiates a large amount of

heat-generated heat and which can be mounted in a limited space, it is
common to use a method for which employs a forced flowing flow of a
refrigerant, using a device such as a pump or a fan, and which causes
radiating heat to be radiated by heat exchange between a device generating
5 heat and the refrigerant ~~is general~~.

The ~~forcible~~-forced cooling control ~~by using~~ a pump or a fan is structured
so as to detect the temperatures of the driving motor and power converter,
compare them with ~~the forcible~~-a cooling start temperature which is set fixedly,
and start the operation of the pump or fan when the detected temperatures
10 reach the ~~forcible~~-set cooling start temperature.

Under this ~~forcible~~-forced cooling control method, the ~~forcible~~-cooling
start temperature is fixed, so that in winter, when the air temperature is low,
the difference between the temperature at the time of operation start of a
driving device for an electric vehicle and the maximum temperature during
15 operation is large.

In the power converter, when ~~the~~-a temperature cycle is added to the
semiconductor element for power conversion control that is used for power
conversion, thermal stress caused by the difference in the linear expansion
coefficient between the members is generated, and a thermal fatigue failure is
20 generated. Therefore, to avoid generation of a failure due to thermal stress, it
is desirable to avoid an excessive temperature difference in the temperature
cycle. Moreover, it is required to ~~forced~~-force cool the semiconductor
element for power conversion control so as to maintain it within the heat
resistance allowable temperature range before high-temperature failure_
25 occurs, or limit the amount of heat.

Further, in the driving motor, since the dielectric strength of the electrical
parts and the magnetic characteristics of magnetic parts are reduced in
correspondence with the temperature rise, it is desirable to cool these parts so

as to prevent the temperature of each of them from exceeding the heat resistance allowable temperature or limit the amount of heat.

Furthermore, when a device such as a pump or a fan is operated, energy consumption ~~is followed by~~ follows, so that when such a device is
5 activated often, the energy consumption is increased and the energy consumption rate of ~~a~~ the vehicle gets worse.

~~Such a problem~~ This is a problem common to not only a cooling system for a driving device for an electric vehicle, but also for various motors using a driving motor.

10

SUMMARY OF THE INVENTION:

An object of the present invention is to provide a cooling system for a motor and a cooling control method ~~suited~~ which is able to prevent a thermal stress failure due to the temperature cycle of a power converter for controlling
15 the power supply to a driving motor.

Another object of the present invention is to provide a cooling system for a motor and a cooling control method ~~suited~~ which is able to prevent a thermal stress failure due to the temperature cycle of a power converter, and to maintain a driving motor and the power converter within ~~the~~ a desired heat
20 resistance allowable temperature range.

Still another object of the present invention is to provide a cooling system for a motor and a cooling control method ~~suited~~ which is able to prevent a thermal stress failure due to the temperature cycle of a power converter, to maintain a driving motor and the power converter within ~~the~~ a
25 desired heat resistance allowable temperature range, and to reduce the energy consumption for ~~forcible~~ forced cooling.

The present invention provides a cooling system for a motor comprising a driving motor, a power converter for controlling the driving motor, and a

cooling means for effecting forced cooling of the driving motor and power converter, wherein: the cooling means has a refrigerant feeding means, a motor temperature detection means for detecting the temperature of the driving motor and for outputting a motor temperature detection signal, a power converter temperature detection means for detecting the temperature of the power converter and outputting it as a power converter temperature detection signal, and a ~~forcible~~-forced cooling control means for referring to the motor temperature detection signal and power converter temperature detection signal and for controlling the refrigerant feeding means and the ~~forcible~~-forced cooling control means has a motor ~~forcible~~-forced cooling control temperature storage means for storing the motor ~~forcible~~-forced cooling control temperature for starting or stopping ~~forcible~~-forced cooling for the driving motor, a power converter operation start temperature storage means for storing the temperature of the power converter at the time of the start of operation ~~start~~ as a power converter operation start temperature, and a power converter ~~forcible~~-forced cooling control temperature rise amount storage means for setting and storing the temperatures for starting and stopping ~~forcible~~-forced cooling for the power converter as a ~~forcible~~-forced cooling control temperature rise amount by the temperature rise amount from the power converter operation start temperature and refers to the power temperature detection signal and power converter temperature detection signal and when the motor temperature detection signal rises up to the motor ~~forcible~~-forced cooling control temperature or the temperature rise amount of the power converter temperature detection signal from the power converter operation start temperature reaches the rise amount of the ~~forcible~~-forced cooling control temperature, starts control of the operation of the refrigerant feeding means.

And, the ~~rise~~-amount of ~~forcible~~-rise in the forced cooling control

temperature includes the ~~forcible~~forced cooling start temperature and ~~forcible~~forced cooling stop temperature and the difference between the ~~forcible~~forced cooling start temperature and the ~~forcible~~forced cooling stop temperature is fixed.

5 Further, the ~~forcible~~forced cooling control means changes the ~~rise-~~amount of rise of ~~forcible~~the forced cooling control temperature according to the power converter operation start temperature.

 Further, the ~~rise-amount of forcible~~rise in the forced cooling control temperature according to the power converter operation start temperature
10 decreases as the power converter operation start temperature rises.

 Further, the ~~forcible~~forced cooling start temperature and ~~forcible~~forced cooling stop temperature components in the ~~rise-amount of forcible~~rise in the forced cooling control temperature decreasing as the power converter operation start temperature rises will reduce the ~~change-~~amount of change in
15 the ~~forcible~~forced cooling stop temperature for the ~~forcible~~forced cooling start temperature.

 Further, the ~~forcible~~forced cooling control means obtains the temperature rise amount from the power converter operation start temperature when the operation is restarted within a short stop period after ending of the
20 operation as a temperature rise from the power converter operation start temperature at the time of preceding operation start.

 Further, the refrigerant feeding means has a refrigerant circulation system for circulating a liquid refrigerant by connecting the driving motor, power converter, radiator with a motor fan, and pump in series and the forcible
25 cooling control means has a fresh air temperature detection means for detecting the fresh air temperature and outputting a fresh air temperature detection signal and controls the motor fan according to the temperature difference between the fresh air and the liquid refrigerant.

Further, the forcible cooling control means, when the fresh air temperature or the liquid refrigerant temperature at the time of operation start of the motor is not higher than the solidifying temperature of the liquid refrigerant, sets the power converter operation start temperature to the solidifying temperature of the liquid refrigerant.

Further, the power converter, when the temperature of the driving motor or the power converter approaches the heat resistance allowable temperature, reduces the conversion output power.

Further, the power converter temperature detection means is built in the chip of semiconductor switching element constituting the power converter.

Further, the present invention provides a cooling system for a motor comprising a driving motor, a power converter for controlling the driving motor, and a cooling means for forced cooling the driving motor and power converter, wherein: the cooling means has a refrigerant feeding means, a motor temperature detection means for detecting the temperature of the driving motor and outputting a motor temperature detection signal, a power converter temperature detection means for detecting the temperature of the power converter and outputting it as a power converter temperature detection signal, and a forcible cooling control means for referring to the motor temperature detection signal and power converter temperature detection signal and controlling the refrigerant feeding means and the forcible cooling control means has a fresh air temperature detection means for detecting the fresh air temperature and outputting a fresh air temperature detection signal, and refers to the motor temperature detection signal, power converter temperature detection signal, and fresh air temperature detection signal, thereby controls the refrigerant feeding means.

Further, the present invention provides a cooling control method for a motor comprising a driving motor, a power converter for controlling the driving

motor, and a cooling means for forced cooling the driving motor and power converter, wherein: the cooling means has a refrigerant feeding means, a motor temperature detection means for detecting the temperature of the driving motor and outputting a motor temperature detection signal, a power
5 converter temperature detection means for detecting the temperature of the power converter and outputting it as a power converter temperature detection signal, and a forcible cooling control means for referring to the motor temperature detection signal and power converter temperature detection signal and controlling the refrigerant feeding means and the forcible cooling
10 control means stores the motor forcible cooling control temperatures for starting and stopping forcible cooling for the driving motor, the temperature of the power converter at the time of operation start as a power converter operation start temperature, and the forcible cooling control temperature rise amount set by the temperature rise amount from the power converter
15 operation start temperature as a temperature for starting or stopping forcible cooling for the power converter and refers to the power temperature detection signal and power converter temperature detection signal and when the motor temperature detection signal rises up to the motor forcible cooling control temperature or the temperature rise amount of the power converter
20 temperature detection signal from the power converter operation start temperature reaches the rise amount of the forcible cooling control temperature, starts control of the operation of the refrigerant feeding means.

BRIEF DESCRIPTION OF THE DRAWINGS:

25 Fig. 1 is a block diagram of the cooling system for the driving device ~~for of an electric vehicle of the~~ according to a first embodiment of the present invention;

Fig. 2 is a ~~forcible~~ cooling characteristic diagram ~~of~~ relating to the first

embodiment;

Fig. 3 is a flow chart of the ~~forcible~~ forced cooling control process of ~~employed by~~ the first embodiment;

Fig. 4 is a ~~forcible~~ cooling control information table ~~of the~~ relating to a
5 second embodiment of the present invention;

Fig. 5 is a temperature characteristic diagram showing changes with time of the temperature of the power converter ~~of the~~ in a third embodiment of the present invention;

Fig. 6 is a block diagram of the cooling system for the driving device
10 ~~for of~~ an electric vehicle ~~of the~~ representing a fourth embodiment of the present invention; and

Fig. 7 is a characteristic diagram showing changes with time of the temperature of the liquid refrigerant (the power converter) of the cooling system for the driving device ~~for of~~ an electric vehicle ~~of the~~ in a fifth
15 embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION:

~~The~~ Various embodiments of the present invention will be explained with reference to Figs. 1 to 6. Further, ~~the~~ common or equivalent constituent parts
20 in the respective embodiments are given the same numerals, and a duplicated explanation thereof will be omitted.

The first embodiment of the present invention will be explained by ~~referring with reference~~ to Figs. 1 and 2. Fig. 1 is a block diagram of the cooling system for the driving device ~~for of~~ an electric vehicle ~~of the~~ according
25 to a first embodiment, ~~and~~; Fig. 2 is a ~~forcible~~ cooling characteristic diagram thereof; ~~and~~ Fig. 3 is a flow chart of the ~~forcible~~ forced cooling control process.

The first embodiment basically ~~has a constitution that for forcible is~~ directed to forced cooling ~~for of~~ the power converter, in which the temperature

of the power converter₁ at the time of start of operation ~~start of an electric~~
vehicle (when the key switch is turned on or the power converter starts
operation)₁ is stored as a power converter operation start temperature, and
the amount of the temperature rise ~~amount of the~~ power converter from the
5 power converter operation start temperature is monitored, and ~~the forcible-~~
forced cooling control of the power converter is started ~~and for forcible.~~ For
cooling ~~for the driving motor~~, the temperature of the driving motor is monitored,
and₁ when the temperature rises up to ~~the forcible-~~ a cooling start temperature
that has been set on the basis of the heat resistance allowable temperature of
10 the driving motor, the ~~forcible-~~ forced cooling control of the motor is started.
Further, the first embodiment has a ~~constitution~~ feature such that, even under
such ~~forcible-~~ forced cooling control, when the temperature of the driving motor
or the power converter approaches the heat resistance allowable temperature
thereof, the conversion output power is reduced.

15 The constitution of the cooling system for the driving device ~~for of an~~
electric vehicle will be explained ~~by referring with reference~~ to Fig. 1. The
cooling system for the driving device ~~for of an~~ electric vehicle has a driving
motor 1₁ such as an inverter driving brushless motor or a commutator motor
for generating the running power of an electric vehicle;₁ a motor temperature
20 detection sensor 2₁ which ~~is operates as~~ a motor temperature detection
means for detecting the temperature of the driving motor 1 and for outputting
a motor temperature detection signal;₁ a power converter 3₁ such as an
inverter or a chopper for controlling the conversion output power for operating
the driving motor 1;₁ a power converter temperature detection sensor 4₁ which
25 is operates as a power converter temperature detection means for detecting
the temperature of the power converter 3 and for outputting a power converter
temperature detection signal;₁ a forced air cooling ~~motor-fan~~ 6 for taking in
fr sh air 5 and sending it as a forced cooling refrigerant;₁ a forced cooling

refrigerant flow path 7 for transferring the forced cooling refrigerant ~~sent from~~
the forced cooling motor-fan 6 to the power converter 2 and the driving motor
1; a main control unit 10 ~~for referring, which is responsive to~~ an instruction
signal output from a key switch 8 or an acceleropedal 9, a motor temperature
5 detection signal output from the motor temperature detection sensor 2, or a
power converter temperature detection signal output from the power converter
temperature detection sensor 4, ~~thereby for~~ controlling the power converter 3
and outputting a run-stop signal to a ~~foreible forced~~ cooling control unit which
will be described later, a ~~foreible forced~~ cooling control unit 11, which is
10 responsive for referring to the motor temperature detection signal output from
the motor temperature detection sensor 2, the power converter temperature
detection signal output from the power converter temperature detection
sensor 4, and the run-stop signal output from the main control unit 10, ~~thereby~~
for controlling the operation of the forced cooling motor fan 6; and a battery
15 12 for supplying DC power to the system~~them~~.

The power converter 3, although a detailed diagramatic-diagrammatic
explanation-illustration thereof is omitted, has a structure ~~that~~which includes a
power control electronic circuit unit 303, that is composed of an inverter or a
chopper, formed on an insulating substrate 302 made of aluminum nitride
20 using, in the form of a semiconductor switching element 301, such as an
IGBT, and it is joined to a cooling substrate 304 made of copper or aluminum,
which is exposed to a refrigerant and radiates heat, by soldering layer 305.
The and the power control electronic circuit unit 303 operates so as to control
the conversion output power supplied to the driving motor 1 from the battery
25 12 on the basis of a control signal received from the main control unit 10.
And, heat generated in the power control electronic circuit unit 303 in
correspondence with the power conversion-supply control operation is
radiated to a refrigerant flowing through the forced cooling refrigerant flow

path 7 via the soldering layer 305 and the cooling substrate 304. The power converter temperature detection sensor 4 is attached onto the insulating substrate 302, so as to be sensitive to the temperature of the insulating substrate 302.

5 The main control unit 10, although ~~a detailed diagrammatic explanation~~
~~diagrammatic illustration thereof~~ is omitted, is mainly ~~composed~~ consists of a
microcomputer composed of a CPU 1001, a memory 1002, and an input-
output circuit 1003. The memory 1002 stores beforehand an operation
control program and control information for reducing the conversion output
10 power in order to reduce the amount of heat so as to maintain the driving
motor 1 and the power converter 3 within the heat resistance allowable range
or to reduce it to zero (for example, the temperature of about 90% of the heat
resistance allowable temperature is set as a conversion output power
reduction start temperature and the heat resistance allowable temperature is
15 set as a conversion output stop temperature).

 The CPU 1001 has an operation control function for executing the
operation control program stored in the memory 1002 when the key switch 8
is turned on (a run instruction), thereby entering the operation control state,
switching the run-stop signal to be output to the ~~forcible~~ forced cooling control
20 unit 11 to "Run", and controlling the power converter 3, on the basis of a
speed instruction signal, according to the ~~working~~ amount of actuation of the
acceleropedal 9, so as to supply the conversion output power according to the
speed instruction signal to the driving motor 1, ~~further monitoring~~. Then, it
monitors the motor temperature detection signal output from the motor
25 temperature detection sensor 2 and the power converter temperature
detection signal output from the power converter temperature detection
sensor 4, ~~reducing~~ reduces the conversion output power in order to reduce
the amount of heat, so as to maintain the driving motor 1 and the power

converter 3 within the desired heat resistance temperature range, ~~controlling~~
~~and controls~~ the power converter 3 so as to reduce the conversion output
power to zero ~~because~~ as the speed instruction signal becomes zero when
the accelerator pedal is released, ~~and further switching.~~ Further, it operates to
5 switch the run-stop signal to be output to the forcible cooling control unit 11 to
"Stop", when the key switch 8 is turned off (a stop instruction), ~~and thereby~~
putting the cooling system into the operation control end (stop) state.

The forcible cooling control unit 11, although a detailed diagrammatic
~~explanation diagrammatic illustration thereof~~ is omitted, is mainly composed
10 consists of a microcomputer composed of a CPU 1101, a memory 1102, and
an input-output circuit 1103. The memory 1102 stores beforehand the
~~forcible-cooling~~ control program and, as control information, motor ~~forcible-~~
~~cooling~~ control temperatures T_{m1} and T_{m2} for starting or stopping ~~forcible-~~
forced cooling ~~for~~ of the driving motor 1 and ~~forcible-cooling~~ control
15 temperature rise amounts $T_{i\alpha}$ and $T_{i\beta}$ that represent the temperature for
starting or stopping ~~forcible-~~ forced cooling ~~for~~ of the power converter 3 ~~is~~ as set
by the amount of temperature rise ~~amount~~ from the power converter operation
start temperature T_{is} .

In consideration of the fact that the motor ~~forcible-cooling~~ control
20 temperatures T_{m1} and T_{m2} for ~~forcible-~~ forced cooling ~~for~~ of the driving motor
1 prevent the dielectric strength of the electrical parts constituting the driving
motor 1 and the magnetic characteristics of the magnetic parts from being
~~reducing-reduced~~ in correspondence with a temperature rise and reduce the
~~forcible-cooling~~ consumption power (energy consumption) by operating the
25 forced cooling motor fan 6, the ~~forcible-cooling~~ start temperature T_{m1} for
starting ~~forcible-~~ forced cooling and the ~~forcible-cooling~~ stop temperature T_{m2}
for stopping ~~forcible-~~ forced cooling are set. For example, the ~~forcible-cooling~~
start temperature T_{m1} is set to 90°C and the ~~forcible-cooling~~ stop temperature

Tm2 is set to 70°C.

The ~~forcible~~-cooling control temperature rise amounts $T_{i\alpha}$ and $T_{i\beta}$ for ~~forcible~~-forced cooling ~~for~~ of the power converter 3 are the ~~forcible~~-cooling start temperature rise amount $T_{i\alpha}$ for starting ~~forcible~~-forced cooling and the
5 ~~forcible~~-cooling stop temperature rise amount $T_{i\beta}$ for stopping ~~forcible~~-forced cooling, and they are temperature rise amounts mainly set in consideration of that the need to prevent failure of the soldering layer 305, which fastens
 adhering the power control electronic circuit unit 303 to the cooling substrate 304, ~~is prevented from failure~~ due to thermal stress by the temperature cycle
10 of the power converter 3, and the ~~forcible~~-forced cooling consumption power (energy consumption) is reduced by operating the forced cooling motor fan 6,
 and as. As shown in Fig. 2, the ~~forcible~~-cooling start temperature rise amounts $T_{i\alpha}$ is set by the temperature rise amount from the power converter operation start temperature T_{is} , and the ~~forcible~~-cooling stop temperature rise
15 amount $T_{i\beta}$ is set by the temperature rise amount from the power converter operation start temperature T_{is} . For example, the ~~forcible~~-cooling start temperature rise ~~amounts~~-amount $T_{i\alpha}$ is set to 50°C and the ~~forcible~~-cooling stop temperature rise amount $T_{i\beta}$ is set 35°C. The difference T_{iy} between the ~~forcible~~-cooling start temperature rise amounts $T_{i\alpha}$ and the ~~forcible~~-cooling
20 stop temperature rise amount $T_{i\beta}$ is fixed (here 15°C), so that the ~~forcible~~-cooling stop temperature rise amount $T_{i\beta}$ may be set by the lowering amount (= difference T_{iy}) from the ~~forcible~~-cooling start temperature rise amounts $T_{i\alpha}$.

The CPU 1101 executes the ~~forcible~~-forced cooling control program when the run-stop signal output from the main control unit 10 is switched to
25 "Run" and stores the power converter temperature detection signal (T_i) output from the power converter temperature detection sensor 4 in the memory 1102 as a power converter operation start temperature T_{is} . Thereafter, the CPU 1101 reads the motor temperature detection signal (T_m) output from the motor

temperature detection sensor 2 and the power converter temperature detection signal (Ti) output from the power converter temperature detection sensor 4 whenever necessary and executes the ~~forcible~~-forced cooling control.

The CPU 1101, under the ~~forcible~~-forced cooling control for ~~forcible~~-forced cooling ~~for~~ of the driving motor 1, monitors the motor temperature detection signal (Tm) output from the motor temperature detection sensor 2,
5 ~~when.~~ When the motor temperature Tm rises up to or becomes higher than the motor ~~forcible~~-cooling start temperature Tm1 for starting ~~forcible~~-forced cooling ~~for~~ of the driving motor 1, ~~operates~~ the forced cooling fan 6 is operated,
10 ~~takes in~~ fresh air 5 is taken in, ~~sends it~~ and the fresh air is sent to the forced cooling refrigerant flow path 7 as a forced cooling refrigerant, ~~and so that~~ forced ~~cools~~ cooling of the driving motor 1 and the power converter 3 takes place. And, by this ~~forcible~~-cooling, when the temperature Tm of the driving motor 1 lowers down to or becomes lower than the motor ~~forcible~~-cooling stop
15 temperature Tm2, the CPU 1101 stops the operation of the forced cooling fan 6; so as to ~~and stops~~ stop the ~~forcible~~-forced cooling.

Further, under the ~~forcible~~-forced cooling control for the power converter 3, when the temperature Ti of the power converter 3 rises up to or becomes higher than the power converter ~~forcible~~-cooling start temperature (Tis + Tia),
20 for which ~~that the~~ ~~forcible~~-cooling start temperature rise amount Tia is added to the power converter operation start temperature Tis, the CPU 1101 operates the forced cooling fan 6, takes in fresh air 5, and sends it to the forced cooling refrigerant flow path 7 as a forced cooling refrigerant, ~~and forced cools~~ thereby to force cool the driving motor 1 and the power converter
25 3. By this ~~forcible~~-forced cooling, when the temperature Tiβ of the power converter 3 lowers down to or becomes lower than the power converter ~~forcible~~-cooling stop temperature (Tis + Tiβ), for which ~~that the~~ ~~forcible~~-cooling stop temperature rise amount Tis is added to the power converter operation

start temperature T_{is} , the CPU 1101 stops the operation of the forced cooling fan 6, so as to and stops stop the forcible forced cooling.

The ~~forcible forced~~ cooling ~~for of~~ the driving motor 1 and the ~~forcible forced~~ cooling ~~for of~~ the power converter 3 are ~~structured so as to share~~
5 carried out by sharing the use of the forced cooling motor fan 6, so that when the ~~forcible forced~~ cooling of either of the driving motor 1 ~~and or~~ the power converter 3 is necessary, the CPU 1101 operates the forced cooling motor fan 6 and ~~controls so as to~~ send the forced cooling refrigerant to the forced cooling refrigerant flow path 7.

10 An example of the control process executed by the CPU 1101 of the ~~forcible forced~~ cooling control unit 11 ~~in order to realize such forcible cooling control will be explained by referring with reference~~ to the control process flow chart shown in Fig. 3.

Step S1:

15 The CPU 1101 monitors the run-stop signal output from the main control unit 10, and, when the signal is switched to "Run", the process goes to Step S2.

Step S2:

20 When the run-stop signal is switched to "Run", the CPU 1101 reads the power converter temperature detection signal output from the power converter temperature detection sensor 4, stores the power converter temperature T_i in the memory 1102 as a power converter operation start temperature T_{is} , and the process goes to Step S3.

Step S3:

25 The CPU 1101 obtains the power converter ~~forcible-cooling start~~ temperature $(T_{is} + T_{i\alpha})$, for which that the ~~forcible-cooling start~~ temperature rise amount $T_{i\alpha}$ is added to the power converter operation start temperature T_{is} , and the power converter ~~forcible-cooling stop~~ temperature $(T_{is} + T_{i\beta})$, for

which ~~that the forcible-cooling~~ stop temperature rise amount $T_{i\beta}$ is added to the power converter operation start temperature T_{is} , stores (sets) them in the memory 1102, and the process goes to Step S4.

Step S4:

- 5 The CPU 1101 reads the motor temperature detection signal (T_m) and the power converter temperature detection signal (T_i), detects the motor temperature T_m and the power converter temperature T_i , and the process goes to Step S5.

Step S5:

- 10 The CPU 1101 compares the detected motor temperature T_m with the motor ~~forcible-cooling~~ start temperature T_{m1} stored in the memory 1102 and branches the process. When the motor temperature T_m is not lower than the motor ~~forcible-cooling~~ start temperature T_{m1} , the CPU 1101 goes to Step S6, and, when the motor temperature T_m is lower than the motor ~~forcible-cooling~~ start temperature T_{m1} , the CPU 1101 goes to Step S7.
- 15

Step S6:

The CPU 1101 puts the forced cooling motor fan 6 into the operation (rotation) state, and the process goes to Step S12.

Step S7:

- 20 The CPU 1101 compares the detected power converter temperature T_i with the power converter ~~forcible-cooling~~ start temperature ($T_{is} + T_{i\alpha}$) stored in the memory 1102 and branches the process. When the power converter temperature T_i is not lower than the power converter ~~forcible-cooling~~ start temperature ($T_{is} + T_{i\alpha}$), the CPU 1101 goes to Step S6, and, when the power
- 25 converter temperature T_i is lower than the power converter ~~forcible-cooling~~ start temperature ($T_{is} + T_{i\alpha}$), the CPU 1101 goes to Step S8.

Step S8:

The CPU 1101 confirms whether the forced cooling motor fan 6 is in

operation or not, and when it is in operation, the process goes to Step S9, otherwise it goes to Step S12.

Step S9:

5 The CPU 1101 compares the detected motor temperature T_m with the motor ~~forcible~~-cooling stop temperature T_{m2} stored in the memory 1102,; and, when the motor temperature T_m is higher than the motor ~~forcible~~-cooling stop temperature T_{m2} , the process goes to Step S12, and while, when the motor temperature T_m is not higher than the motor forcible cooling stop temperature T_{m2} , the process goes to Step S10.

10 Step S10:

The CPU 1101 compares the detected power converter temperature T_i with the power converter ~~forcible~~-cooling stop temperature $(T_{is} + T_{i\beta})$ stored in the memory 1102,; and, when the power converter temperature T_i is higher than the power converter ~~forcible~~-cooling stop temperature $(T_{is} + T_{i\beta})$, the
15 process goes to Step S12, and while, when the power converter temperature T_i is not higher than the power converter ~~forcible~~-cooling stop temperature $(T_{is} + T_{i\beta})$, the CPU 1101 goes to Step S11.

Step 11:

The CPU 1101 puts the forced cooling motor fan 6 into the rotation stop
20 state, and the process goes to Step S12.

Step 12:

The CPU 1101 confirms the run-stop signal output from the main control unit 10 and branches the process. When the run-stop signal is switched to "Run", the CPU 1101 goes to Step S4, and, when it is switched to "Stop", it
25 goes to Step S13.

Step S13:

The CPU 1101 executes the operation end process of putting the forced cooling motor fan 6 into the stop state, and ~~finishes the operation~~process is

concluded.

According to ~~such forcible~~ this forced cooling control, the ~~forcible~~ cooling ~~for of~~ the power converter 3 is controlled on the basis of the amount of temperature rise ~~amount~~ from the power converter operation start temperature,
5 which is set in consideration of the fact that the power converter 3 is prevented from failure by thermal stress due to the temperature cycle and the ~~forcible-forced~~ cooling power consumption is reduced by operating the forced cooling motor fan 6, so that the temperature difference is small even in winter when the temperature at the time of operation start is low and the temperature
10 cycle can be kept constant through all seasons, ~~thus.~~ Thus thermal stress can be prevented from excessively increasing, and the ~~forcible-forced~~ cooling power consumption is reduced. Further, the ~~forcible~~ cooling ~~for of~~ the driving motor 1 is controlled on the basis of the ~~forcible~~ cooling control temperature set in consideration of the fact that the dielectric strength of the electrical parts
15 constituting the driving motor 1 and the magnetic characteristics of the magnetic parts are prevented from being reduced ~~reducing~~ in correspondence with a temperature rise, and the ~~forcible-forced~~ cooling consumption power is reduced by operating the forced cooling motor fan 6, so that the performance and life of the driving motor 1 are prevented from degradation, and the forcible
20 cooling power consumption is reduced.

In this embodiment, as a forced cooling refrigerant, fresh air 5 is used. However, the present invention is not limited theretoto it.

Further, for ~~the forcible-forced~~ cooling control, two stages of control of the "forcibleforced cooling operation" and "stop" are illustrated. However, it
25 may be changed to multi-stage control that in which the ~~forcible-forced~~ cooling force (the rotational speed of the forced cooling fan 6) is changed according to the temperature.

~~The~~ A second embodiment of the present invention will be explained by

~~referring with reference to~~ Figs. 1 to 4. Fig. 4 ~~is~~ shows a ~~forcible-forced~~ cooling control information table ~~of relating to~~ the second embodiment.

The second embodiment has a ~~constitution that~~ feature in which the ~~forcible-cooling~~ start temperature rise amount $T_{i\alpha}$ for starting ~~forcible-forced~~ cooling₁ which is a forcible cooling control temperature rise amount in forcible cooling for the power converter 3₁ and the forcible cooling stop temperature rise amount T_{is} for stopping ~~forcible-forced~~ cooling in the forcible cooling control characteristics shown in Fig. 2 in the first embodiment mentioned above₁ are set by variables changing according to the power converter operation start temperature T_{is} . ~~Concretely~~ More specifically, when the power converter operation start temperature T_{is} rises, the ~~forcible-cooling~~ start temperature rise amount $T_{i\alpha}$ and the ~~forcible-cooling~~ stop temperature rise amount T_{is} are reduced. The ~~reduction-amount of the forcible-reduction of~~ the cooling stop temperature rise amount T_{is} due to rising of the power converter operation start temperature $T_{i\beta}$ is smaller than the ~~reduction-amount of reduction of the forcible-cooling~~ start temperature rise amount $T_{i\alpha}$. Fig. 4 illustrates the ~~forcible-cooling~~ start temperature rise amount $T_{i\alpha}$ and the forcible cooling stop temperature rise amount T_{is} for this power converter operation start temperature $T_{i\beta}$.

~~And, when forcible~~ When forced cooling control for a cooling system for a driving device ~~for of~~ an electric vehicle₁ structured as according to the block diagram shown in Fig. 1 is executed on the basis of such control information, although the thermal stress acting on the power converter 3 increases, the operation of the ~~forced-cooling~~ motor fan 6 at low temperature is suppressed, so that the power consumption for ~~forcible-cooling~~ can be reduced ~~more~~.

~~Concretely~~ More specifically, in the control ~~of~~ provided in the second embodiment, a process is added ~~that to~~ obtain and set the power converter ~~forcible-cooling~~ start temperature ($T_{is} + T_{i\alpha}$) and the power converter ~~forcible~~

cooling stop temperature ($T_{is} + T_{i\beta}$) at Step S3, in which the CPU 1101 of the ~~forcible-cooling~~ control unit 11 selects the ~~forcible-cooling~~ start temperature rise amount $T_{i\alpha}$ and the ~~forcible-cooling~~ stop temperature rise amount $T_{i\beta}$ to be added to the power converter operation start temperature T_{is} according to
5 the power converter operation start temperature T_{is} .

~~The~~ A third embodiment of the present invention will be explained ~~by~~
with reference ~~referring~~ to Figs. 1 to 5. Fig. 5 is a temperature characteristic
diagram showing changes with time of the temperature of the power converter
of the third embodiment.

10 During the stop period₁ after the end of operation-~~end~~, the temperatures
of the driving motor 1 and the power converter 3 slowly lower due to natural
cooling. Therefore, when the operation is restarted within a short period after
the end of operation-~~end~~, the temperatures of the driving motor 1 and the
power converter 3 are considerably higher than the environmental
15 temperature₁ and thermal stress remains in the power converter 3. The
thermal stress of the power converter 3 in correspondence with a temperature
rise due to restart of the operation in such a state is desirably considered to
be caused by the temperature rise from the power converter operation start
temperature at the time of a preceding operation start₁ which is an operation
20 start after a long stop period₁ causing a disappearing of the thermal stress.

The third embodiment, in consideration of such residual thermal stress
of the power converter 3, as the aforementioned power converter operation
start temperature T_{is} in the first embodiment, adopts the power converter
operation start temperature at the time of a preceding operation start₁ which is
25 an operation start after a long stop period₁ causing the disappearing of
thermal stress₁ when the operation is restarted within a short stop period after
the end of operation-~~end~~.

~~Concretely~~ More specifically, as shown in Fig. 5, when the operation is

started by turning on the key switch 8 at the time t_1 , ~~after the~~ when an electric vehicle ~~is~~ has been stopped for many hours and the temperature T_i of the power converter 3 approaches the environmental temperature, the power converter operation start temperature at that time is T_{is1} , and thereafter, by repetitive running and stopping of the electric vehicle, the temperatures T_m and T_i of the driving motor 1 and the power converter 3 rise and lower repeatedly, ~~and when.~~ When the temperature T_m or T_i of the driving motor 1 or the power converter 3 ~~becomes~~ reaches the motor ~~forcible~~-cooling start temperature T_{m1} or the power converter ~~forcible~~-cooling start temperature $(T_{is} + T_{i\alpha})$ or higher, the forced cooling motor fan 6 is operated, and forced cooling of the driving motor 1 and the power converter 3 are ~~is started to be forced cooled, and.~~ Then, when the temperature T_m or T_i of the driving motor 1 or the power converter 3 ~~becomes~~ reaches the motor ~~forcible~~-cooling stop temperature T_{m2} or the power converter ~~forcible~~-cooling stop temperature $(T_{is} + T_{i\beta})$ or lower, the forced cooling motor fan 6 is stopped, whereby ~~and the forcible~~ forced cooling is stopped.

When the key switch 8 is turned off at the time t_2 , and the operation is finished, and the system enters the stop state, the temperatures T_m and T_i of the driving motor 1 and the power converter 3 lower due to natural heat radiation.

Thereafter, when the operation is restarted at the time t_3 , when the temperature T_i of the power converter 3 is higher than the environmental temperature, the power converter operation start temperature at this time is T_{is2} . In this state, in the power converter 3, the thermal stress due to temperature rise by heat generation at the time of the preceding operation remains, and when the power converter ~~forcible~~-cooling start temperature $(T_{is} + T_{i\alpha})$ and the power converter ~~forcible~~-cooling stop temperature $(T_{is} + T_{i\beta})$ are set by adding the ~~forcible~~-cooling start temperature rise amount $T_{i\alpha}$ and

the ~~forcible-cooling~~ stop temperature rise amount T_{is} to the power converter operation start temperature T_{is2} , there is the possibility that the ~~forcible-cooling~~ control temperature for the power converter 3 may become excessively high.

5 Therefore, the third embodiment is structured so that, in a case of operation restart after such an operation stop for a short time, the temperature of the power converter 3 lowers sufficiently and the power converter operation start temperature T_{is1} at the time of the preceding operation start, which is an operation start after a long stop period causing the disappearing of thermal
10 stress to disappear, is adopted as the power converter operation start temperature T_{is} for setting the power converter ~~forcible-cooling~~ start temperature ($T_{is} + T_{i\alpha}$) and the power converter ~~forcible-cooling~~ stop temperature ($T_{is} + T_{i\alpha}$) to be used for ~~forcible~~ forced cooling control ~~for of~~ the power converter 3.

15 To realize this ~~forcible~~ forced cooling control, the CPU 1101 of the ~~forcible~~ forced cooling control unit 11 of the third embodiment has a clock function, and the memory 1102 has an information holding function for storing and holding a desired stop period which has been preset in consideration of the time necessary for sufficient lowering of the temperature of the power
20 converter 3, and for holding the power converter operation start temperature T_{is} even during stop. And, the CPU 1101, in the operation ending operation at Step S13, performs a process of storing and holding the operation end date and time in the memory 1102, at. At Step S2, it reads the operation start date and time and obtains the stop period from the previous operation end date and time, when. When the stop period is longer than the desired stop period,
25 it rewrites and sets the temperature T_{is2} of the power converter 3 at that time with the power converter operation start temperature T_{is1} and, when the stop period is within the desired stop period, it sets the time T_{is1} of the power

converter 3 at the time of the previous start with the power converter operation start temperature T_{is} .

The ~~others~~ other features are the same as those of the aforementioned embodiments.

5 According to the third embodiment ~~aforementioned~~, as described above, the same ~~forcible~~ forced cooling effect as that of the aforementioned embodiments is obtained; and, even when the operation is restarted after a short-time stop, the temperature difference in the power converter 3 is not large and the temperature cycle can be controlled within a fixed range, so that
10 a highly reliable driving device for an electric vehicle can be realized.

~~The~~ A fourth embodiment of the present invention will be explained ~~by~~ with reference ~~referring~~ to Figs. 2 to 6. Fig. 6 is a block diagram of the cooling system of the driving device for an electric vehicle ~~of~~ according to the fourth embodiment.

15 The fourth embodiment has a structure such that the heat of the power converter 3 and the driving motor 1 is ~~radiated~~ carried away by a liquid refrigerant, and the heat of the liquid refrigerant is radiated to fresh air by a radiator cooled with a motor fan. The ~~and the~~ heat radiation capacity (operation and stop of the motor fan) of the radiator, that is cooled with a
20 ~~motor fan~~ to by fresh air is, controlled. Namely, in a state ~~that in which~~ a liquid refrigerant is circulated and the units are ~~forced~~ force cooled, when the temperature difference between the liquid refrigerant and the fresh air is large, heat is radiated by natural ventilation because the radiation capacity of the radiator is large; and, when the temperature difference between the liquid
25 refrigerant and fresh air is small, heat radiation is promoted by ~~forcible~~ forced ventilation because the radiation capacity of the radiator is small.

In the fourth embodiment, as a refrigerant circulation system for circulating a refrigerant, a forced cooling refrigerant flow path 7 ~~ef~~ coming out

from a water pump 13, sequentially passing the power converter 3, the driving motor 1, and a radiator 14 with a motor fan for radiating heat to fresh air 5, and returning to the water pump 13 is formed. Further, a fresh air temperature detection sensor 15, which ~~is~~ serves as a fresh air temperature detection means for detecting the temperature of fresh air 5 and outputting a fresh air temperature detection signal (Ta) is provided.

~~And, the forcible~~ The forced cooling control unit 11 controls the water pump 13, in the same way as ~~with control for~~ of the forced cooling motor fan 6 ~~is effected~~, when the water pump 13 is operated, ~~and whereby~~ a refrigerant is circulated so as to execute ~~forcible~~ forced cooling;. For this purpose, the forced cooling control unit 11 refers to the fresh air temperature detection signal (Ta) output from the fresh air detection sensor 15, when the temperature difference Ta-f between the fresh air temperature Ta and the liquid refrigerant temperature Tf ~~becomes~~ reaches the preset radiator forcible heat radiation start temperature difference Tw1 or becomes smaller, and it operates the motor fan of the radiator 14 so as to generate ~~forcible~~ forced ventilation; ~~and when.~~ When the temperature difference ~~becomes~~ reaches the radiator forcible heat radiation stop temperature difference Tw2 or becomes larger, it executes the control for stopping the motor fan. The temperature difference Ta-f (the radiator ~~forcible~~ heat radiation start temperature difference Tw1 and the radiator ~~forcible~~ heat radiation stop temperature difference Tw2) is set according to the heat radiation characteristics of the radiator 14 which is cooled with a ~~motor~~ fan.

The liquid refrigerant temperature Tf is desirably detected by installing a temperature detection sensor in the forced cooling refrigerant flow path 7. However, in the fourth embodiment, there is a relationship ~~that~~ in which the liquid refrigerant temperature Tf and the power converter temperature Ti are almost constant, so that the power converter temperature detection signal (Ti)

is appropriated. Further, the system may be structured so as to appropriate a motor temperature detection signal (T_m) or to install a temperature detection sensor (not shown in the drawing) in the radiator 14 ~~with a motor fan and~~ appropriate a temperature detection signal output from the temperature
5 detection sensor.

Since the operation of the ~~motor fan of for cooling~~ the radiator 14 ~~with a motor fan~~ is controlled like this, the system is structured so that the ~~forcible-~~
forced cooling control unit 11 presets and stores the radiator ~~forcible-heat~~
radiation start temperature difference $Tw1$ and the radiator ~~forcible-heat~~
10 radiation stop temperature difference $Tw2$ in the memory 1102. ~~The and the~~
CPU 1101, when the water pump 13 is operated and a refrigerant is circulated
so as to execute ~~forcible-cooling~~, refers to a fresh air temperature detection
signal output from the fresh air detection sensor 15, detects a fresh air
temperature T_a , when the temperature difference T_a-f between the fresh air
15 temperature T_a and the liquid refrigerant temperature T_f ~~becomes-reaches~~ a
preset radiator ~~forcible-heat~~ radiation start temperature $Tw1$ or becomes
higher, operates the motor fan of the radiator 14, ~~and when.~~ When the
temperature difference ~~becomes-reaches~~ the radiator ~~forcible-heat~~ radiation
stop temperature $Tw2$ or becomes lower, ~~executes~~ the control process of
20 stopping the motor fan is executed.

The ~~others-other features~~ are the same as those of the aforementioned
embodiments.

According to the fourth embodiment, as described above-
~~aforementioned~~, the same ~~forcible-cooling~~ effect as that of the aforementioned
25 embodiments is obtained, and the driving motor 1 and the power converter 3
can be ~~forced-force~~ cooled by a liquid refrigerant having a large heat capacity,
so that the cooling efficiency is increased and the system can be made
compact. Further, the radiator 14 ~~with a motor fan~~ radiates heat naturally

with the ~~motor~~-fan stopped until the temperature difference ~~becomes~~reaches the radiator ~~forcible~~-heat radiation start temperature difference T_{w1} or larger, so that the power (energy) consumption for operating the ~~motor~~-fan and for generating ~~forcible~~forced ventilation can be reduced.

5 ~~The~~A fifth embodiment of the present invention will be explained by ~~referring with reference~~ to Figs. 2 to 7. Fig. 7 is a characteristic diagram showing changes with time of the temperature of the liquid refrigerant (the power converter) of the cooling system of the driving device for an electric vehicle ~~of~~according to the fifth embodiment.

10 For a liquid refrigerant to be used for ~~forcible~~-cooling, a liquid refrigerant ~~having is used that has~~ a solidifying temperature lower than an expectable fresh air temperature in an environment ~~that in which~~ an electric vehicle is used ~~is used~~. However, the fresh air temperature may become lower than the solidifying temperature of the liquid refrigerant due to ~~coming of~~
15 unexpected cold temperatures. In such a case, the liquid refrigerant ~~is will~~ become solidified. However, ~~since the electric vehicle is driven,~~ the liquid refrigerant is heated and melted by heat generated by the driving motor and power converter as the electric vehicle is driven. ~~However, when~~ When the ~~forcible forced~~ cooling control system ~~is functioned~~ functions in this state and
20 the water pump and radiator provided with a ~~motor~~-fan are operated, there is the possibility that the liquid refrigerant may be over-cooled and ~~re-solidified~~may re-solidify.

 The fifth embodiment is structured so as to prevent such re-solidification of ~~a the~~ liquid refrigerant ~~and when~~. When the temperature of ~~a the~~ liquid
25 refrigerant or fresh air at the time of ~~operation~~-start of operation of an electric vehicle is not higher than the solidifying temperature of the liquid refrigerant, ~~to use~~ the liquid refrigerant solidifying temperature is used as a power converter operation start temperature T_s is set for ~~forcible forced~~ cooling control.

~~Concretely~~More specifically, as shown in Fig. 7, under the ~~forcible-forced~~ cooling control in the state ~~that in which~~ the power converter operation start temperature T_{is3} , corresponding to the temperature of fresh air or the temperature of ~~a~~the liquid refrigerant₁ is not higher than the solidifying temperature T_{fm} of ~~a~~the refrigerant flowing in the forced cooling liquid refrigerant flow path 7, the solidifying temperature T_{fm} is set as a power converter operation start temperature T_{is} , and the ~~forcible-forced~~ cooling control process is executed.

By doing this, the ~~forcible-forced~~ cooling system is operated at a considerably higher temperature than the solidifying temperature T_{fm} of the liquid refrigerant, so that the liquid refrigerant can be prevented from re-solidification₁ and the power consumption can be reduced.

In the embodiments ~~explained-described~~ above, the control and ~~forcible~~forced cooling control for the driving motor 1 are structured so as to be executed separately by the main control unit 10 and the ~~forcible-forced~~ cooling control unit 11. However, the control and ~~forcible-forced~~ cooling control for the driving motor 1 may be structured so as to be executed by one main control unit 10.

The power converter temperature detection sensor 4 of the respective embodiments ~~explained-described~~ above is attached onto the insulating substrate 302 of the power control electronic circuit unit 303 of the power converter 3. However, when a temperature detection sensor is built in the chip of the semiconductor switching element 301₁ such as an IGBT, the temperature detection sensor built in the chip may be substituted therefor.

Further, the present invention is not limited to the cooling system and cooling control method for the driving device ~~for-of~~ an electric vehicle, as mentioned above₁ and can be used as a cooling system and a cooling control method for various motors comprising a driving motor, a power converter for

controlling the driving motor, and a cooling means for forced cooling of the driving motor and power converter, wherein the cooling means has a refrigerant feeding means, a motor temperature detection means for detecting the temperature of the driving motor and outputting a motor temperature
5 detection signal, a power converter temperature detection means for detecting the temperature of the power converter and outputting it as a power converter temperature detection signal, and a ~~forcible~~-forced cooling control means ~~for~~-referring-responsive to the motor temperature detection signal and power converter temperature detection signal ~~and~~ for controlling the refrigerant
10 feeding means.

~~According to~~-In the cooling system and cooling control method for a motor ~~of~~-according to the present invention, the power converter is ~~forced-~~force cooled so as to keep the difference between the temperature thereof at the time of the start of operation ~~start~~-and the temperature thereof during
15 constant operation-~~constant~~, so that the power converter can be prevented from failure due to thermal stress.

Further, the driving motor and power converter can be maintained within the heat resistance allowable temperature range.

Furthermore, due to ~~forcible~~-forced cooling, the energy consumption can
20 be reduced.